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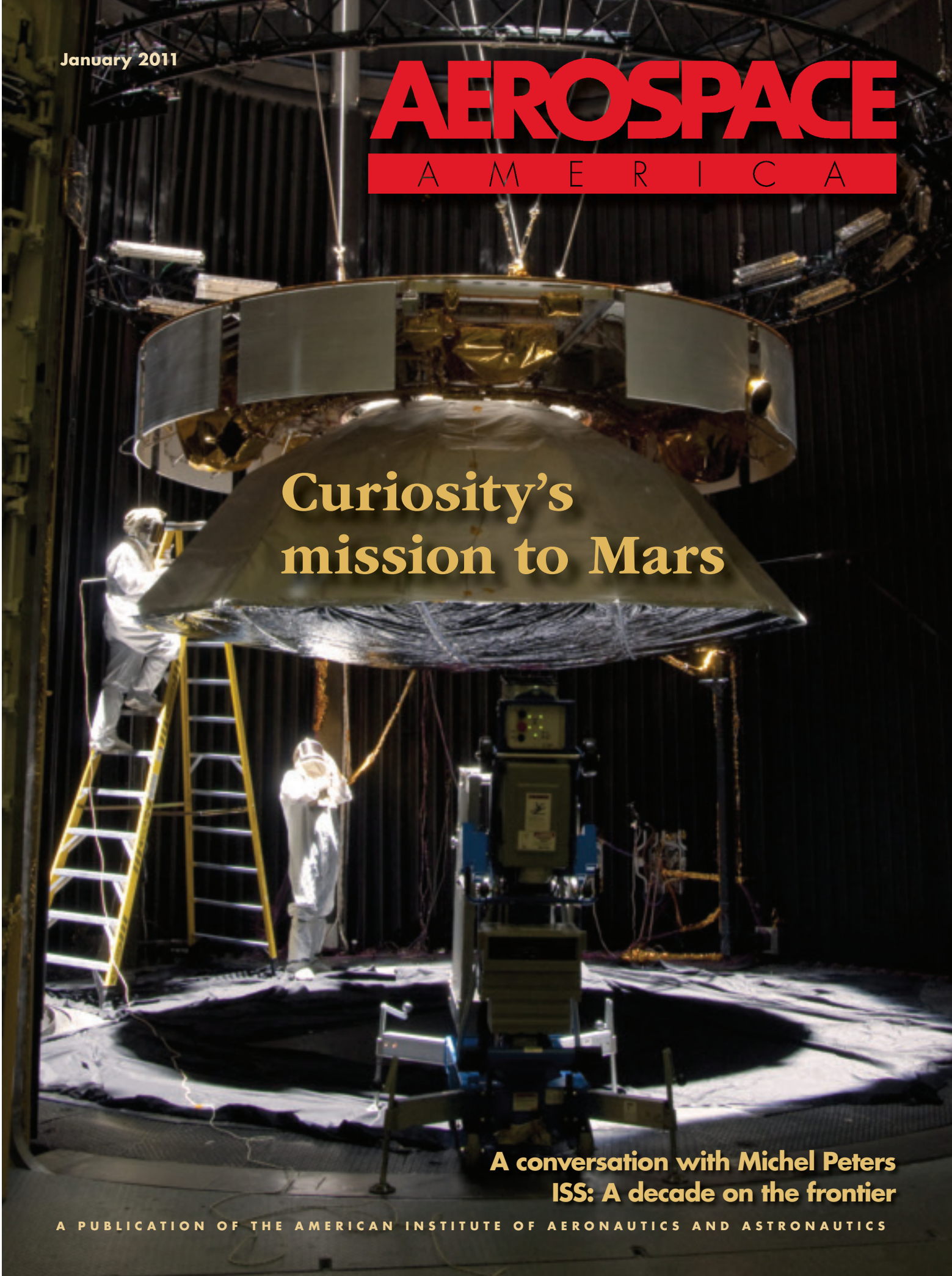

Curiosity's mission to Mars

A conversation with Michel Peters

ISS: A decade on the frontier

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Son of Apollo

A new space capsule takes shape

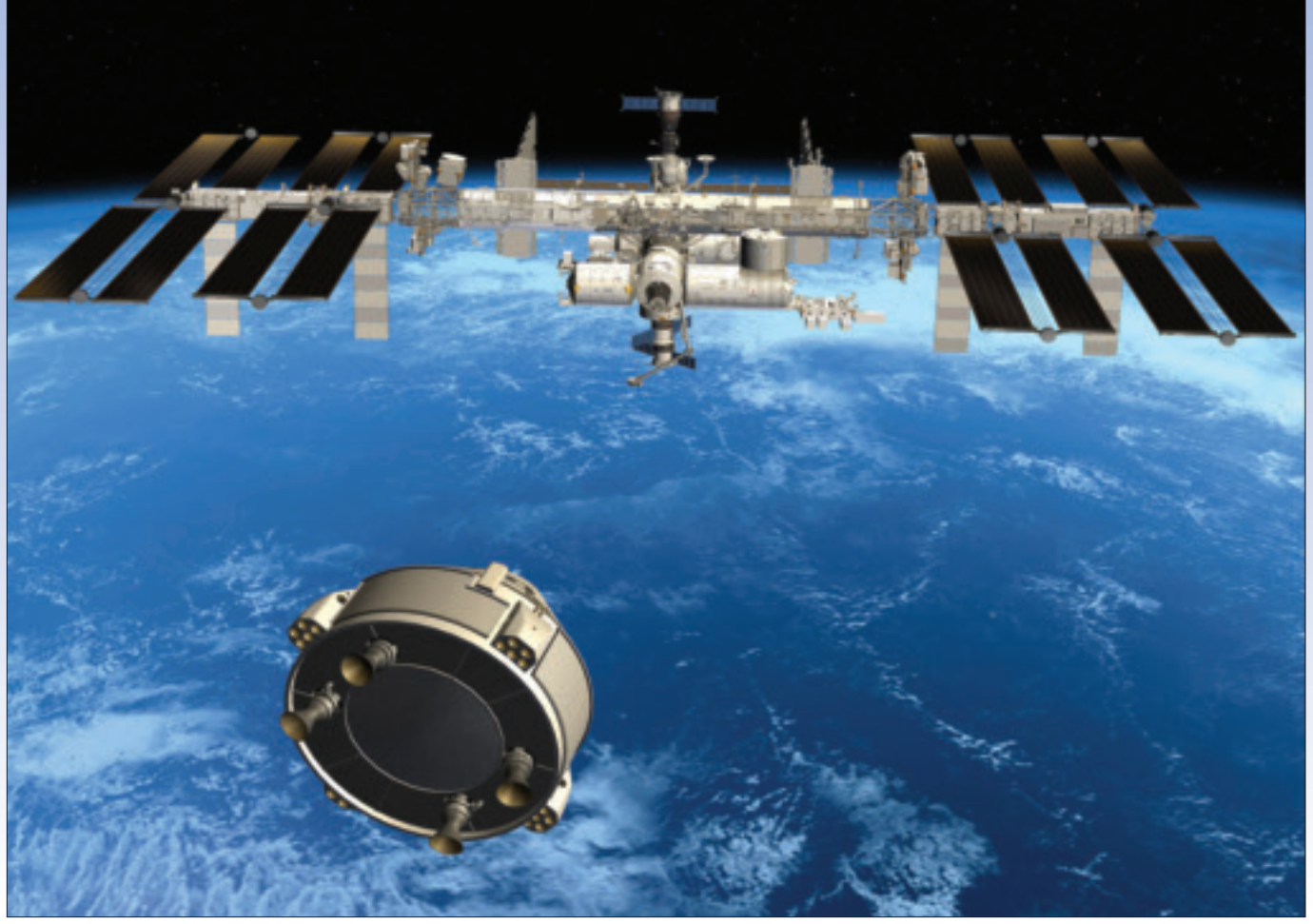
CCDev, NASA's effort to stimulate development of a space transportation capability in industry, has emphasized safety, reliability, and economy. The result is a space capsule reminiscent of the Apollo command module of the 1960s and 1970s, geared for short trips to and from the ISS. And like the Apollo module, its crew accommodations will be more spartan than those of the space shuttle.

by Frank Sietzen Jr.
Contributing writer

NASA's Commercial Crew Development (CCDev) program is the agency's effort to seed the development of a commercial capability for launching cargo to the ISS. Its aim, says the program's announcement, is to "stimulate efforts within the private sector to develop and demonstrate safe, reliable, and cost-effective space transportation capabilities." The project manages two COTS (Commercial Orbital Transportation Services) partnership agreements totaling $500 million for commercial cargo transportation demonstration flights. After a competition, two U.S. firms, Orbital Sciences and SpaceX, were selected for the activity.

First contracts

In February, through an open competition, NASA also awarded Space Act Agreements totaling $50 million to five more firms, toward commercial crew launch development. All the crew funds came from stimulus money provided in the American Recovery and Reinvestment Act of 2009, not from the NASA budget. The companies are Blue Origin in Kent, Washington; Boeing in Houston, Texas; Paragon Space Development in Tucson, Arizona; Sierra in Louisville, Colorado; and United Launch Alliance in Centennial, Colorado.



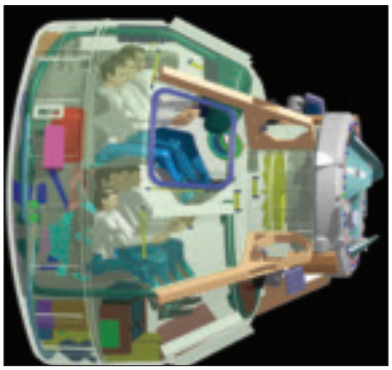
The agreements are for the design of crew-carrying spacecraft and related technology demonstrations, and investigations for future commercial support of human spaceflight. In its announcement NASA said, "Space Act Agreements will stimulate efforts within the private sector to develop and demonstrate human spaceflight capabilities." Out of the $50 million, Blue Origin will receive $3.7 million, Boeing $18 million, Paragon Space Development $1.4 million, Sierra Nevada $20 million, and United Launch Alliance $6.7 million. The project is being managed from NASA Johnson.

Using the stimulus funds, plus money received during the earlier CCDev competition, Boeing chose to accelerate design and development of a crew capsule it calls CST-100, for Commercial Space Transport 100 (100 refers to the 100 km from the ground to LEO). As a partner, Boeing selected Bigelow Aerospace, whose engineers are developing a possible space tourism destination for the Boeing capsule: a multipassenger space station comprised of inflatable modules. The company is currently testing scale models of the units in space. Bigelow could provide its space station to sovereign governments that cannot afford their own space program; this leased space could be used for scientific research.

Vehicle features

What emerged from Boeing designers is a capsule shape reminiscent of the Apollo Command Module flown to the Moon and to the Skylab space station in the 1960s and 1970s. The last such capsule was launched to rendezvous and dock with a Soyuz space vehicle in July 1975. The command module's manufacturer was a company later acquired by Boeing, Rockwell International (formerly North American Rockwell). "We have a great deal of capsule design heritage from Apollo, from the OSP [orbital spaceplane] program, and from our work on the Orion program," says Keith Reiley, Boeing's Commercial Crew Development Program Manager at the company's facility in Houston.

The spacecraft as proposed consists of two parts: a cabin called the crew module (CM), and an unpressurized unit beneath it called the service module (SM). The capsule, according to Reiley, is "bigger than Apollo and smaller than [today's] Orion." The Apollo command module was a cone 3.9 m wide at its base. The Orion's base is currently 5.02 m wide. The CST-100's base is 4.5 m wide, placing it be-



The CST-100 can accommodate a crew of up to seven.

tween Apollo and Orion. But there are major differences with Orion that make the new spacecraft closer in capability to its Apollo predecessor.

Limited accommodations, lower cost

Crew accommodations on Apollo were limited. It had no waste management facilities (the astronauts used bags) and no galley for food preparation. Hot water guns were used to reconstitute food contained in plastic pouches. An oven was carried on only two flights—Apollo 8, to provide astronauts Frank Borman, Jim Lovell, and Bill Anders a hot Christmas turkey dinner, and Apollo-Soyuz, to furnish the crew with hot meals. Orion promises better waste management facilities than those of the shuttle, and better galley equipment. The CST-100 has neither accommodation. "This is pretty primitive as far as the crew is concerned, more like Apollo," says Reiley. One reason is that the spacecraft is designed for very brief return flights from the ISS or Bigelow missions, trips lasting only a day. Another is to keep development and production costs as low as possible.

The capsule can carry up to seven astronauts arrayed in two tiers of seats. Missions with smaller crews can fly customer cargo in place of the empty seats. Windows are arranged so that the commander and pilot have rendezvous visibility, and the rest of the crew can see out via forward and side windows. Over a forward hatch on top of the capsule is a rounded ascent cover. In the center of the capsule is a main egress and entry hatch, and arrayed around the base is a series of thrusters. Boeing is using a proprietary ablative heatshield to cover the base. A parachute system is stored in mortars located around the apex, and an airbag landing system is stored above the heat shield, which is jettisoned during descent. The capsule is designed for a hard-surface landing but can be recovered in water if necessary.

The small SM consists of a short rectangle whose surface is covered in four places by radiators, four quads of thrusters, and a thermal shield that covers the bottom. An umbilical connection is also attached to the capsule. The most prominent features of the SM are two nozzles, one extending from each side.

Feeding the engines is a hypergolic bipropellant system that also fuels the thrusters. The engines provide a unique launch escape system that pressurizes the engines with 1,000 psia for a high-thrust firing that "pushes" both the CM and SM off a malfunctioning booster. The SM is then jettisoned, and the CM lands by parachute. This same engine system is used in space to maneuver the vehicle to the rendezvous target. Reiley notes the abort system can fire during any phase of the ascent: "There are no black zones," he says.

Testing activities

Boeing and Bigelow have conducted a test and validation risk-reduction program for the spacecraft to verify vehicle designs and to identify key technologies that must be matured before being integrated into the vehicle.

For simplicity and low cost, the abort apparatus uses a single pressurization system for both abort and on-orbit operations. Utilizing previous work done on the Atlas II sustainer engine, Boeing is using an ablative nozzle technology similar to that of the Rocketdyne Lance engine. The demonstration program will test engine ignition, performance, and combustion stability using a series of bipropellant fuel and oxidizer mixtures.

Previously, Boeing had tested a material called BLA (Boeing lightweight ablator) on a 5-ft-wide carrier test article. The test team formed and bonded reinforcing honeycomb to the heat shield structure, spreading batches of the BLA onto the honeycomb test structure in a single application. The CCDev testing effort uses a BLA simulated heat shield cured in an autoclave. The shield, which measures 4.2 m, demonstrates a production-ready capability. The tests will give Boeing engineers experience in assembly, production, transportation, and pressure testing for heat shields attached to the base of prospective CM capsules.

At its Avionics System Integration Facility in Houston, Boeing is testing prospective avionics software and hardware in simulated flight conditions. The company has also conducted tests involving the aluminum alloy pressure vessel of the CM to assess how the vehicle handles full pressure of the cabin in different flight environments. A full-scale boilerplate mass simulator has been used to test various elements of the recovery system, including

airbag deployment, multiple descents using different parachute configurations, and water recovery stabilization of the capsule. Bigelow constructed the boilerplate model and tested it at the company's Aquatic Test Facility in Las Vegas, Nevada.

Also under way are life support air revitalization system demonstrations using Bigelow assembled components. Demonstrations of integrated guidance and navigation systems for autonomous rendezvous and docking have drawn on previous Boeing systems developed with DARPA.

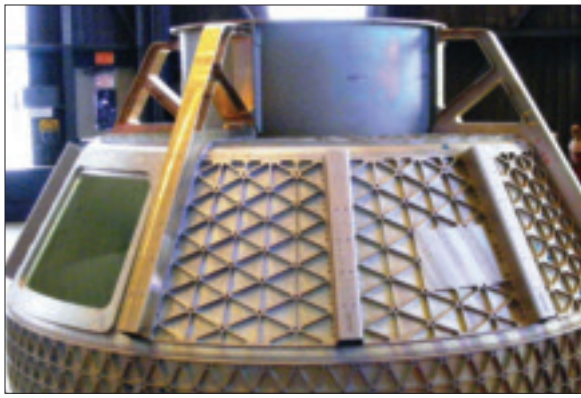
The CST-100 is designed to transport astronauts to 250-n.mi. destinations at 51.6-deg inclinations for ISS missions, and 225 n.mi. at 35-deg inclinations for Bigelow station missions. The spacecraft can operate for up to 48 hr of autonomous free flight but is primarily aimed at a day-one rendezvous with a day-two backup. It can remain docked to a station for up to 210 days while drawing less than 1 kW of trickle power. It will be compliant with NASA's human rating requirements.

Boeing is working with potential human-rated launch vehicle providers to ensure compatibility with the CST-100 capsule. This compatibility should enable the flexibility required to reach the desired commercial launch price targets.

The markets

Bob Bigelow, founder of Bigelow Aerospace, told reporters at the Farnborough Air Show last July that he was proceeding with expansion of his Nevada facilities to accommodate more rapid development of his space station's inflatable modules. He displayed his customary confidence, telling the assembled reporters that his firm is building a new plant, also in Nevada, that has no other purpose than "mass production" of inflatable habitat modules. He added that no less than 75% of all the money he expects to take from customers leasing space stations and buying seats on rockets will be passed on to launch providers like Boeing. "We expect a significant Christmas card" from them, he said. Bigelow has constructed a full-sized mock-up of the CST crew module to test the interior layout and external arrangement of grappling attachments and crew hand-holds for use during Bigelow and ISS docking.

According to Reiley, Boeing is not planning for Bigelow to be its primary launch customer. "Our primary focus is NASA as our customer," he explains, "but we are working with Bigelow Aerospace to support their orbiting space complexes as an expansion of our market." Depending on funding, first test launches could take place in three years, with first commercial crew missions by 2015.



Pressure testing of the crew compartment structure anchors was conducted in September at the Bigelow Aerospace facility in Las Vegas.

NASA releases RFI

NASA released an RFI this summer to further test industry's interest in supporting commercial crews. The purpose was to gather information that would help the agency plan an overall strategy for the development and demonstration of a commercial crew transport capability and to receive comments on NASA human-rating technical requirements currently in the draft stage.

The agency held a meeting at Headquarters in August to review CCDev progress. Officials said 35 companies had responded to a May 21 NASA solicitation seeking input on the commercial crew initiative. NASA predicts that it could fund up to four providers if Congress approves the full $5.8 billion included in President Obama's initial budget request.

Funding uncertainties

The NASA authorization mandates a government-developed capsule as well as funding for commercial crew transport. Thus it is not readily apparent how the

Boeing is working closely with Bigelow Aerospace to support their space structures.

The Orion capsule was a larger, more complex structure.

commercial space transportation system will fare if it competes directly with a Lockheed Martin Orion derivative. Nor has NASA announced if it will recompete the Orion contract as the new "multipurpose crew transportation vehicle" called for in the legislation. The original Orion CEV for ISS or Moon missions was designed for launch aboard the Ares I, and Orion's weight growth eventually made it necessary for the spacecraft itself to complete the orbit insertion burn.

Congressional instructions call for a deep-space vehicle based on the CEV's capsule shape but not necessarily of the same size or complexity as Orion. Boeing is avoiding the launch vehicle selection initially by making its vehicle compatible for launch aboard one of the Atlas, Delta, or Falcon rockets—a first since the Apollo command/service module was designed for launch aboard Saturn I and V boosters. A smaller, simpler, cheaper Lockheed capsule would seem to be a head-to-head competitor for Boeing's new entry.

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On October 25 NASA issued an announcement seeking proposals from U.S. industry to further advance commercial crew space transportation concepts and mature the design and development of system elements. Awards will result in funded Space Act Agreements.

Multiple awards are expected to be announced by March 2011 for terms of up to 14 months. A total of approximately $200 million is expected to be available for awards, but funding is dependent on the FY11 appropriations from Congress.

If Boeing and Lockheed—and possibly SpaceX, with a crewed Dragon—succeed in bringing their vehicles to market, it would mark the first time that multiple production and manufacturing capabilities for manned spacecraft were in operation. Keeping the two sets of space capsules—one commercial and one federal—from eliminating each other in the new U.S. human space program may prove as difficult as building the machines themselves.